

AMEREN MISSOURI LABADIE ENERGY CENTER

LABADIE SULFUR REDUCTION PROJECT

STANDARD OPERATING PROCEDURE

**TELEDYNE ADVANCED POLLUTION INSTRUMENTATION
MODEL T100
UV FLUORESCENCE SO₂ ANALYZER**



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TABLE OF CONTENTS

	PAGE
1. Instrument Overview	1 of 56
2. Instrument Description	4 of 56
3. Installation and Set-Up	10 of 56
4. Field Calibration Control Plan	19 of 56
5. Primary Calibration	31 of 56
6. One-Point Quality Control Checks and Level I Span Checks	39 of 56
7. Routine Operation	46 of 56
8. Preventive Maintenance	49 of 56
9. Troubleshooting	53 of 56

LIST OF TABLES

Table	Title	Section	Page
1-1	TAPI Model T100 Specifications	1	3 of 56
4-1	Control Limits	4	30 of 56
8-1	T100 Preventative Maintenance Schedule	8	51 of 56

LIST OF FORMS

Title	Section	Page
Form 5-1: SO ₂ Calibration Form	5	54 of 56
Form 7-1: SO ₂ System Routine Check Form	6	55 of 56
Form 8-1: Instrument Maintenance Log	8	56 of 56

1. INSTRUMENT OVERVIEW

The Teledyne Advanced Pollution Instrumentation Model T100 (also referred to as T100) UV Fluorescence SO₂ Analyzer is a microprocessor controlled analyzer that determines the concentration of sulfur dioxide (SO₂), in a sample gas drawn through the instrument's sample chamber where it is exposed to ultraviolet light, which causes any SO₂ present to fluoresce. The instrument measures the amount of fluorescence to determine the amount of SO₂ present in the sample gas.

The T100's exceptional stability is achieved with the use of an optical shutter to compensate for sensor drift and a reference detector to correct for changes in UV lamp intensity. Additionally an advanced optical design combined with a special scrubber, called a "kicker" that removes hydrocarbons (which fluoresces similarly to SO₂) prevents inaccuracies due to interferents.

Calibration of the instrument is performed in software which stores SO₂ concentration measurements made when specific, known concentrations of SO₂ are supplied to the analyzer. The microprocessor uses these calibration values along with other performance parameters such as the sensor offset, UV lamp intensity and the amount of stray light present and measurements of the temperature and pressure of the sample gas to compute the final SO₂ concentration.

Built-in data acquisition capability, using the analyzer's internal memory, allows the logging of multiple parameters including averaged or instantaneous concentration values, calibration data, and operating parameters such as pressure and flow rate. Stored data are easily retrieved through the serial port or optional Ethernet port via APICOM software or from the front panel, allowing operators to perform predictive diagnostics and enhanced data analysis by tracking parameter trends. Multiple averaging periods of one minute to 365 days are available for over a period of one year.

The T100 analyzer is designated as Federal Equivalent Method Number EQSA-0495-100 as per 40 CFR Part 53 when operated under the following conditions:

- Range: Any range from 50 parts per billion (ppb) to 10 parts per million (ppm).
- Ambient temperature range of 5 °C to 40 °C.
- Line voltage range of 100-120 VAC or 220-240 VAC, at 50 or 60 Hz.
- Sample filter: Equipped with PTFE filter element in the internal filter assembly.
- Sample flow of 650 +/- 65 cm³/min.
- Vacuum pump (internal) capable of 14"Hg Absolute pressure @ 1 slpm or better.

- Software settings:

Dynamic span	OFF
Dynamic zero	OFF
Dilution factor	OFF
AutoCal	ON or OFF
Dual range	ON or OFF
Auto-range	ON or OFF
Temp/Pressure compensation	ON

Under this designation, the analyzer may be operated with or without the following optional equipment:

- Rack mount with chassis slides.
- Rack mount without slides, ears only.
- Zero/span valve options.
- Internal zero/span (IZS) option with either:
 - SO2 permeation tube - 0.4ppm at 0.7 liter per minute; certified/uncertified.
 - SO2 permeation tube - 0.8 ppm at 0.7 liter per minute; certified/uncertified.
 Under the designation, the IZS option cannot be used as the source of calibration.
- 4-20mA isolated analog outputs.
- Status outputs.
- Control inputs.
- RS-232 output.
- Ethernet output.
- Zero air scrubber.
- 4-20mA, isolated output.

For a more detailed description of the analyzer's operation, see Section 2 of this SOP and Chapter 9 of the Instrument Manual. Instrument specifications are presented in Table 1.

Table 1: Teledyne API Model T100 Basic Unit Specifications	
Parameter	Description
Ranges (Physical Analog Output)	Min: 0-50 ppb Full Scale Max: 0-20,000 ppb Full Scale (selectable, dual ranges and auto ranging supported)
Measurement Units	ppb, ppm, $\mu\text{g}/\text{m}^3$, mg/m^3 (selectable)
Zero Noise ¹	< 0.2 ppb (RMS)
Span Noise ¹	< 0.5% of reading, above 50 ppb
Lower Detectable Limit ²	0.4 ppb
Zero Drift	< 0.5 ppb/24 hours
Span Drift	< 0.5% of full scale/24 hours
Lag Time ¹	20 seconds
Rise/Fall Time ¹	<100 sec to 95%
Linearity	1% of full scale
Precision ¹	0.5% of reading above 50 ppb
Sample Flow Rate	650 cm^3/min . $\pm 10\%$
Power Requirements	100V-120V, 220V-240 V, 50/60 Hz
Analog Output Ranges	10 V, 5 V, 1 V, 0.1 V (selectable)
Recorder Offset	$\pm 10\%$
Standard I/O	1 Ethernet: 10/100Base-T 2 RS-232 (300 – 115,200 baud) 2 USB device ports 8 opto-isolated digital outputs 6 opto-isolated digital inputs 4 analog outputs
Optional I/O	1 USB com port 1 RS485 8 analog inputs (0-10V, 12-bit) 4 digital alarm outputs Multidrop RS232 3 4-20mA current outputs
Environmental	Installation category (over-voltage category) II; Pollution degree ²
Operating Temperature Range	5 - 40 °C (with EPA Equivalency)
Humidity Range	0 - 95% RH, non-condensing
Dimensions HxWxD	7" x 17" x 23.5" (178 mm x 432 mm x 597 mm)
Weight	31 lbs (14 kg) 35.7 lbs (16 kg) with internal pump
¹ As defined by the USEPA.	
² Defined as twice the zero noise level by the USEPA.	

2. INSTRUMENT DESCRIPTION

The instrument is more easily described by separating it into three sections: the flow control system, the optical detection system, and the electronics.

2.1 Flow Control System

The flow control system is concerned with proper control of the sample gas flow within the instrument. A diaphragm pump, located downstream of all other sample-handling components, maintains sufficient vacuum to draw a steady, continuous stream of sample air (or calibration gas) through the analyzer. Sample air is introduced to the instrument through a "Sample" inlet port located on the rear panel of the instrument. Additional "Span" and "Zero" inlet ports are installed on the rear panel of the analyzer as the analyzers for the monitoring program have been purchased with this option from the manufacturer (TAPI). These ports are connected to an external source of calibration gas. Switchable solenoid valves, located immediately downstream of the "Span" and "Zero" ports, allow selectable control of which gas source will be sampled by the analyzer.

After entering the pneumatic flow path, the gas is next drawn through the inner tube of a hydrocarbon "kicker", which removes any hydrocarbons that are present in the gas stream while leaving the SO₂ concentration unaffected. The hydrocarbon "kicker" operates on a selective permeable membrane principle. It consists of an inner tube surrounded entirely by a larger-diameter outer, or "shell" tube. The walls of the inner tube are made of a permeable membrane that is porous to hydrocarbon molecules only. The hydrocarbons pass through the inner tube wall, driven by a differential partial pressure developed by passing the sample gas through a capillary tube to reduce its pressure, and then feeding the reduced-pressure gas stream to the shell side of the "kicker", where it is finally drawn through the vacuum pump and is subsequently exhausted.

After exiting the tube side of the "kicker", the sample stream flows to the light-tight fluorescence chamber where it undergoes analysis. Exiting the fluorescence chamber, the sample stream is drawn through a special flow control assembly including a glass capillary tube, which volumetrically controls the sample flow rate. Depending on the size of the capillary bore supplied with the instrument, this (nominal) flow rate is ~0.65 liter per minute (LPM). A series of transducers located upstream of the capillary tube continuously monitor the flow rate, pressure and temperature of the sample gas stream. These measurements are converted to electronic signals for user access, storage and (for the temperature and pressure data) use in analyzer internal calculation of SO₂ concentrations.

The sample stream is then drawn through the outer “shell” tube of the kicker assembly (as described above) and then through the vacuum pump, where it is expelled through an exhaust port located on the rear panel of the instrument.

The flow control assembly is located in the exhaust vacuum manifold (refer to Figure 1) to maintain a constant flow rate of the sample gas through the instrument. This assembly consists of:

- A critical flow orifice.
- Two o-rings: Located just before and after the critical flow orifice, the o-rings seal the gap between the walls of assembly housing and the critical flow orifice.
- A spring: Applies mechanical force needed to form the seal between the o-rings, the critical flow orifice and the assembly housing.

The most important component of this flow control assembly is the critical flow orifice. Critical flow orifices are a remarkably simple way to regulate stable gas flow rates. They operate without moving parts by taking advantage of the laws of fluid dynamics. By restricting the flow of gas through the orifice, a pressure differential is created. This pressure differential combined with the action of the analyzer’s pump draws the gas through the orifice.

As the pressure on the downstream side of the orifice (the pump side) continues to drop, the speed that the gas flows through the orifice continues to rise. Once the ratio of upstream pressure to downstream pressure is greater than 2:1, the velocity of the gas through the orifice reaches the speed of sound. As long as that ratio stays at least 2:1 the gas flow rate is unaffected by any fluctuations, surges, or changes in downstream pressure because such variations only travel at the speed of sound themselves and are therefore cancelled out by the sonic shockwave at the downstream exit of the critical flow orifice.

The actual flow rate of gas through the orifice (volume of gas per unit of time), depends on the size and shape of the aperture in the orifice. The larger the hole, the more gas molecules, moving at the speed of sound, pass through the orifice. Because the flow rate of gas through the orifice is only related to the minimum 2:1 pressure differential and not absolute pressure the flow rate of the gas is also unaffected by degradations in pump efficiency due to age.

The critical flow orifice used in the T100 is designed to provide a flow rate of 650 cm³/min.

Much attention has been paid to keeping the sample gas in its original condition until analysis. Sample lines are constructed from FEP Teflon. All other non-Teflon materials encountered by

the sample stream prior to analysis are either stainless steel or glass. The sample flow rate is designed to keep sample residency and transit times to a minimum, thereby minimizing adsorption effects. To remove particles in the sample gas, the analyzer is equipped with a Teflon membrane filter of 47 mm diameter (also referred to as the sample filter) with a 1 µm pore size. The filter is accessible through the front panel, which folds down, and should be changed according to the suggested maintenance schedule listed in Table 8-1.

2.2 Optical Detection System

The T100 UV Fluorescence SO₂ Analyzer determines the concentration of sulfur dioxide (SO₂), in a sample gas drawn through the instrument. It requires that sample and calibration gases be supplied through the sample chamber where the sample gas is exposed to ultraviolet light; this exposure causes the SO₂ molecules to change to an excited state (SO₂*). As these SO₂* molecules decay into SO₂ they fluoresce. The instrument measures the amount of fluorescence to determine the amount of SO₂ present in the sample gas. The optical design of the T100's sample chamber optimizes the fluorescent reaction between SO₂ and UV Light and assure that only UV light resulting from the decay of SO₂* into SO₂ is sensed by the instruments fluorescence detector.

UV radiation is generated by a lamp specifically designed to produce a maximum amount of light of the wavelength needed to excite SO₂ into SO₂* (214 nm) and a special reference detector circuit constantly measures lamp intensity (refer to (Equation 9-2)). A Photo Multiplier Tube (PMT) detects the UV given off by the SO₂* decay (330 nm) and outputs an analog signal. Several focusing lenses and optical filters ensure that both detectors are exposed to an optimum amount of only the right wavelengths of UV.

To further assure that the PMT only detects light given off by decaying SO₂* the pathway of the excitation UV and field of view of the PMT are perpendicular to each other and the inside surfaces of the sample chamber are coated with a layer of black Teflon® that absorbs stray light.

The source of excitation UV light for the T100 is a low pressure zinc-vapor lamp. An AC voltage heats up and vaporizes zinc contained in the lamp element creating a light producing plasma arc. Zinc-vapor lamps are preferred over the more common mercury vapor lamps for this application because they produce very strong emission levels at the wavelength required to convert SO₂ to SO₂*, 213.9 nm.

The lamp used in the T100 is constructed with a vacuum jacket surrounding a double bore lamp element. The vacuum jacket isolates the plasma arc from most external temperature fluctuations. The jacket also contains thermal energy created by the lamp's operation therefore helping the lamp

to heat up and maintain proper vaporization temperature. Light is emitted through a 20 mm x 5 mm portal.

The amount of fluoresced UV produced in the sample chamber is much less than the intensity of excitation UV source lamp. Therefore a much more sensitive device is needed to detect this light with enough resolution to be meaningful. The T100 uses a Photo Multiplier Tube or PMT for this purpose.

A PMT is typically a vacuum tube containing a variety of specially designed electrodes. Photons enter the PMT and strike a negatively charged photo cathode causing it to emit electrons. These electrons are accelerated by a high voltage applied across a series of special electrodes called dynodes that multiply the amount of electrons until a useable current signal is generated. This current increases or decreases with the amount of detected light.

Inherent in the operation of both the reference detector and the PMT are a minor electronic offsets. The degree of offset differs from detector to detector and from PMT to PMT and can change over time as these components age. To account for these offsets the T100 includes a shutter, located between the UV Lamp and the source filter that periodically cuts off the UV light from the sample chamber. This happens every 30 minutes. The analyzer records the outputs of both the reference detector and the PMT during this dark period and factors them into the SO₂ concentration calculation.

2.3 Electronics

The core of the analyzer is a microcomputer that controls various internal processes, interprets data, makes calculations, and reports results using specialized firmware developed by Teledyne API. It communicates with the user as well as receives data from and issues commands to a variety of peripheral devices through a separate printed circuit assembly to which the CPU is mounted: the motherboard. The motherboard is directly mounted to the rear panel and collects data, performs signal conditioning duties and routes incoming and outgoing signals between the CPU and the analyzer's other major components.

Concentration data of the T100 are generated by the Photo Multiplier Tube (PMT), which produces an analog current signal corresponding to the brightness of the fluorescence reaction in the sample chamber. This current signal is amplified to a DC voltage signal (front panel test parameter **PMT**) by a PMT preamplifier printed circuit assembly (located on top of the sensor housing). **PMT** is converted to digital data by a bi-polar, analog-to-digital converter, located on the motherboard.

In addition to the PMT signal, a variety of sensors report the physical and operational status of the analyzer's major components, again through the signal processing capabilities of the motherboard. These status reports are used as data for the SO₂ concentration calculation (e.g. pressure and temperature reading used by the temperature/pressure compensation feature) and as trigger events for certain warning messages and control commands issued by the CPU. They are stored in the CPU's memory and, in most cases, can be viewed through the front panel display.

Finally, the CPU issues commands (also over the I2C bus) to a series of relays and switches located on a separate printed circuit assembly, the relay board (located in the rear of the chassis on its own mounting bracket) to control the function of key electromechanical devices such as valves and heaters. The following text provides a brief description of the primary functions for these electronic components. The user should refer to Chapter 9 in the Instruction Manual as well as the schematics that appear at the end of the Instruction Manual for more detailed information.

- a) The CPU Card The unit's CPU card, installed on the motherboard located inside the rear panel, is a low power (5 VDC, 720mA max), high performance, Vortex 86SX-based microcomputer running Windows CE. Its operation and assembly conform to the PC 104 specification. The CPU includes two types of non-volatile data storage: a Disk on Module (DOM) and an embedded flash chip.
- b) The Sensor Module Electronically, the T100 sensor module is a group of components that: create the UV light that initiates the fluorescence reaction between SO₂ and O₃; sense the intensity of that fluorescence; generate various electronic signals needed by the analyzer to determine the SO₂ concentration of the sample gas, and sense and control key environmental conditions such as the temperature of the sample gas and the PMT.
- c) The Photomultiplier Tube (PMT) The T100 uses a photo multiplier tube (PMT) to detect the amount of fluorescence created by the SO₂ and O₃ reaction in the sample chamber.
- d) The PMT Cooling System The performance of the analyzer's PMT is significantly affected by temperature. Variations in PMT temperature are directly reflected in the signal output of the PMT. Also the signal to noise ratio of the PMT output is radically influenced by temperature as well. The warmer The PMT is, the noisier its signal becomes until the noise renders the concentration signal useless. To alleviate this problem a special cooling system exists that maintains the PMT temperature at a stable, low level.

- e) The PMT Preamplifier The PMT preamplifier board amplifies the PMT signal into a useable analog voltage that can be processed by the motherboard into a digital signal to be used by the CPU to calculate the SO₂ concentration of the gas in the sample chamber.
- f) The Pneumatic Sensor Board The flow and pressure sensors of the T100 are located on a printed circuit assembly just behind the PMT sensor. The signals of this board are supplied to the motherboard for further signal processing. All sensors are linearized in the firmware and can be span calibrated from the front panel.
- g) The Relay Board The relay board is the central switching unit of the analyzer. It contains power relays, status LEDs for all heated zones and valves as well as valve drivers, thermocouple amplifiers, power distribution connectors and the two switching power supplies of the analyzer. The relay board communicates with the motherboard over the I²C bus and is the main board for trouble-shooting power problems of any kind.
- h) Status LEDs & Watch Dog Circuitry Thirteen LEDs are located on the analyzer's relay board to indicate the status of the analyzer's heating zones and valves as well as a general operating watchdog indicator.
- i) The Motherboard This printed circuit assembly provides a multitude of functions including A/D conversion, digital input/output, PC-104 to I²C translation, temperature sensor signal processing and is a pass through for the RS-232 and RS-485 signals.
- j) A to D Conversion Analog signals, such as the voltages received from the analyzer's various sensors, are converted into digital signals that the CPU can understand and manipulate by the Analog to Digital converter (A/D). Under the control of the CPU, this functional block selects a particular signal input and then converts the selected voltage into a digital word.
- k) Sensor Inputs The key analog sensor signals are coupled to the A/D through the master multiplexer from two connectors on the motherboard. 100K terminating resistors on each of the inputs prevent cross talk from appearing on the sensor signals.
- l) Thermistor Interface This circuit provides excitation, termination and signal selection for several negative coefficient, thermistor temperature sensors located inside the analyzer.

3. INSTALLATION AND SET-UP

3.1 UNPACKING

Unpack the instrument according to the guidelines presented in Chapter 3 of the Operation Manual. Verify that there is no apparent external shipping damage. If damage has occurred, please advise the shipper first, then Teledyne API. Included with the analyzer is a printed record of the final performance characterization performed on the instrument at the factory. It is titled *Final Test and Validation Data Sheet (P/N 04551)*. This record is an important quality assurance and calibration record for this instrument. It should be placed in the quality records file for this instrument.

With no power to the unit, carefully remove the top cover of the analyzer and check for internal shipping damage by carrying out the following steps:

- a. Remove the locking screw located in the top, center of the front panel;
- b. Remove the two flat head, Phillips screws on the sides of the instrument;
- c. Slide the cover backwards until it clears the analyzer's front bezel, and;
- d. Lift the cover straight up.
- e. Inspect the interior of the instrument to ensure that all circuit boards and other components are in good shape and properly seated.
- f. Check the connectors of the various internal wiring harnesses and pneumatic hoses to ensure that they are firmly and properly seated.
- g. Verify that all of the optional hardware ordered with the unit has been installed. These are listed on the paperwork accompanying the analyzer.

3.2 ASSEMBLY AND SYSTEM INTEGRATION

3.2.1 Assembly and Installation

Assemble the instrument according to the guidelines presented in Chapter 3 of the TAPI T100 Operation Manual. The monitoring station design calls for rack-mounting of the analyzer. Install the male parts of the supplied slide rails on the sides of the analyzer and the corresponding female parts of the rail slides in the instrument rack. Ensure there will be adequate vertical clearance with respect to other rack-mounted instrumentation and that the location of the analyzer in the rack will permit easy access for service and maintenance. Mate the rail slide sections and install the analyzer in the rack. Ensure the analyzer slides smoothly on the rails into the rack and back out in the fully extended position. Table 3-3 in

Section 3.3.1 of the TAPI T100 Operation Manual lists the minimum required ventilation clearance for the instrument.

3.2.2 Pneumatic Interconnections

- (a) All materials employed for sample delivery to the analyzer shall be comprised of either borosilicate glass, FEP Teflon, or type 316 stainless steel. All connections to the analyzer for gas/sample delivery will be made using 1/4" O.D. (3/16" I.D.) FEP Teflon tubing and type 316 stainless steel fittings. Leak-tight compression fittings (e.g., Swagelok) are typically used for connecting tubing to port fittings. Sample air delivery lines should not exceed 10 feet in total length.
- (b) Consult the monitoring station system pneumatic interconnection diagram. The SO₂ analyzers incorporate an internal solenoid valve (for switching of the gas stream supplied to the analyzer from sample air to calibration gas in support of automatic calibration checks). Make sample air delivery connections from the sample intake to the analyzer by connecting a length of 1/4" O.D. Teflon tubing from the sample intake system to the "Sample" inlet port on the rear bulkhead of the analyzer.
- (c) Consult the monitoring station system pneumatic interconnection diagram and make the proper interconnections between the on-site source of calibration gas (used for automatic SO₂ calibration checks) and the "Zero" and "Span" inlet ports located on the rear bulkhead of the analyzer. Use 1/4" O.D. Teflon tubing to make these interconnections.
- (d) The solenoid valve(s) used for routing calibration gas to the SO₂ analyzer in support of conducting automatic zero/span checks will be activated by the datalogger. **Ensure the lines that deliver the calibration gas to the analyzer incorporate an atmospheric bypass dump (i.e., a "tee" union fitting with an unobstructed vent)** as indicated in the site pneumatic interconnection diagram. This will ensure that calibration gases are delivered to the analyzer at (or near) atmospheric pressure.
- (e) Connect the port on the rear panel of the analyzer labeled "Exhaust" to the site exhaust manifold, where the exhaust will be expelled to the outside atmosphere.

3.2.3 Electrical Interconnections

Use standard single- or multi-pair, stranded (18~20 AWG), shielded, low-voltage signal cable with PVC or similar jacketing for all low-voltage electrical connections. Use U.L.-approved and/or National Electric Code (NEC)-approved materials for making all higher (line) voltage connections. Attach the power cord to the analyzer and plug it into a power outlet capable of carrying at least 10 Amps of current at your AC voltage and that it is equipped with a functioning earth ground. Ground terminals on all line-voltage power connections shall be used. Terminations on low-voltage wiring may be made using bare wire, solderless or soldered techniques and hardware, as indicated. Care should be exercised to ensure reliable connections. Exposed bare wire lengths at termination points should be kept as short as possible to avoid short-circuits. All wiring runs should be neatly organized, dressed, tagged for identification, and routed for ready access and serviceability.

- (a) Connect the on-site data recording device(s) to the analog output channel(s) located at the rear of the instrument. The data recording devices typically consist of a datalogger and strip chart recorder. (These connections are specified in the site electrical interconnection diagram.) Note the polarity and the specified full scale input voltage range for these devices and be sure they match the corresponding full scale output voltage range from the analyzer.
- (b) The site operation plan calls for automatic zero/span checks. Make the appropriate electrical connections from the on-site datalogger control output terminals to the solenoid valve(s) that route delivery of the calibration gases used for these checks (these connections are specified in the site electrical interconnection diagram). Be sure to observe correct wiring polarity. The analyzer is equipped with internal solenoid valves and these valves are specified for this purpose, the electrical wiring from the datalogger control outputs will be connected to the specified Ethernet and Control Input port terminals located on the analyzer rear panel.
- (c) Connect the supplied line voltage power cord to a convenient electrical outlet supplying 115VAC at 60Hz.

3.2.4 Configure Analyzer Operating Parameters

After the electrical and pneumatic connections are made, perform an initial functional check. Turn on the instrument. The pump and exhaust fan should start immediately. The display will show a momentary splash screen of the Teledyne API logo and other information during

the initialization process while the CPU loads the operating system, the firmware and the configuration data.

The analyzer should automatically switch to Sample Mode after completing the boot-up sequence and start monitoring the gas. However, there is an approximately one hour warm-up period before reliable gas measurements can be taken. During the warm-up period, the front panel display may show messages in the Parameters field.

Because internal temperatures and other conditions may be outside specified limits during the analyzer's warm-up period, the software will suppress most warning conditions for 30 minutes after power up. If warning messages persist after the 60 minutes warm up period is over, investigate their cause using the troubleshooting guidelines in Section 10.1.1 of the TAPI T100 Operation Manual. After the analyzer's components have warmed up for at least 60 minutes, verify that the software properly supports any hardware options that were installed.

The TAPI 100E SO₂ analyzer features a menu-driven, interactive informational display and control panel to facilitate analyzer set-up and interrogation by the user. Virtually all control functions and configuration parameters are accessed and set by the user using this feature. It is also used to view current operating status indications, SO₂ measurement data, the current time, date, analyzer I.D. number and other information. This procedure for configuring analyzer operating parameters assumes the user is interfacing with the analyzer using the front panel display and controls. For information on navigating through the analyzer's software menus, refer to the menu trees described in Appendix A.1 of the TAPI T100 Operation Manual.

The Final Test and Validation Data Sheet (P/N 04551) shipped with the instrument lists the factory-set values before the instrument left the factory. To view the current values of these parameters toggle the <TST TST> control buttons on the analyzer's front panel to scroll through the list of parameters that the instrument is configured for. Remember until the unit has completed its warm up these parameters may not have stabilized.

The user can alternatively interrogate, configure and download information from the analyzer using the analyzer's Ethernet port connected to a local or remote IBM-compatible personal computer (PC) using a Windows[™] operating system and running the TAPI communications software. Connections can be made using supplied cables. A cellular modem and broadband service to the site must be supplied to support remote communications via the Ethernet port. The user should refer to Appendix B in the TAPI

T100 Operation Manual and the TAPI Communications Software Manual for detailed information on effecting and utilizing this communication capability.

3.2.4.1 Program-Specific Configuration

From the Main Screen on the analyzer front panel display, sub-menus can be accessed to view information and configure the analyzer's operating parameters as-needed. Chapter 3 in the Operation Manual provides comprehensive descriptions of menu topics, organization and content, as well as descriptions of the significance and range of configuration choices the user may select. Chapter 4 in the Operation Manual provides comprehensive description of the set up menu topics. To avoid unnecessary duplication, this SOP will limit itself to instruction for configuring the analyzer operating parameters that are specifically required for this monitoring program. It is assumed that operators have read and familiarized themselves with the Operation Manual, and are consequently capable of using the menu-driven display and control panel to effect the following specified configuration settings.

- (a) Verify the reporting range settings:
 - (1) Unit of Measure: PPB
 - (2) Analog Output Reporting Range: 500.0 PPB
 - (3) Mode Setting: SNGL
- (b) Set the expected SO₂ span gas concentration. This should be 80% of the concentration range for which the analyzer's analog output range is set, or 400 PPB.
- (c) Set the internal time-of-day clock that the analyzer uses to time stamp COM port messages and DAS data entries. Set the clock for local standard time (LST).
- (d) Set the analog output signal type to DC voltage and the level to 0 to 1 VDC.

Program-specific configuration of the analyzer is now complete. If any operational problems are evident or suspected, refer to and implement the problem resolution guidelines presented in Step (b) above. If analyzer operation is normal, it should be

allowed to operate for a minimum overnight “conditioning” period prior to performing a primary calibration (refer to Section 4 in this SOP for calibration procedures).

3.2.5 Analog Output Step Check and Manual Calibration

Analog Output Step Check can be used as a step test to check the accuracy and proper operation of the analog outputs. The test forces all four analog output channels to produce signals ranging from 0% to 100% of the full scale range in 20% increments. This test is useful to verify the operation of the data logging/recording devices attached to the analyzer. Refer to Section 4.87.3 in the TAPI T100 Operation Manual for the proper procedure for performing an Analog Output Step Test.

For the highest accuracy, the voltages of the analog outputs should be manually calibrated. Calibration is done through the instrument software with a voltmeter connected across the output terminals. Adjustments are made using the control buttons by setting the zero-point first and then the span point. Refer to Section 4.8.4.3 in the TAPI T100 Operation Manual for further details.

3.2.5.1 Required Materials and Equipment

- (a) TAPI T100 Operation Manual.
- (b) Certified voltmeter (NIST-traceable) with a minimum resolution of 4 digits and a minimum accuracy of ± 0.001 VDC (e.g., Fluke 287 or equivalent).

3.2.5.2 Procedure

- (a) Connect the voltmeter test leads across the analyzer’s analog output voltage terminals (refer to Figure 4-24 in the analyzer Operation Manual for the location of these terminals). Be sure to match the polarity of the test leads and voltage output terminals.
- (b) To make the manual adjustments, the **AOUT** auto-calibration features must be **OFF** (refer to Section 4.8.4.2 of the TAPI T100 Operation Manual). Activate the **ANALOG I/O CONFIGURATION MENU** from the **DIAG** Menu (refer to Figure 4-17 in the TAPI T100 Operation Manual), then proceed to step (c).
- (c) From the **ANALOG I/O CONFIGURATION** screen, Press **ENTR** and then press **SET>** to select the analog output channel to be configured. When the correct analog output channel is selected, press **EDIT** and then press **SET>** to turn the **CONC_OUT_CH OVERANGE:** to **ON**, the **CONC_OUT_CH REC OFS:** to **0 mV**, the

CONC_OUT_CH_AUTO CAL: to **OFF** and the **CON_OUT_CH CALIBRATED:** to **NO**.

- (d) Now press **CAL** to select the “Zero” (bottom of scale) adjustment mode. The analyzer screen will display the **CONC_OUT_1_VOLT-Z:** value and keys in the lower portion of the screen that will increase/decrease the analog output by 100, 10, or 1 counts. Continue adjustments until the voltage measured at the output of the analyzer and/or the input of the recording device matches the value in the upper right hand corner of the display to a voltage tolerance of 0.000 VDC \pm 0.001 V when the full scale voltage output is 0 – 1 VDC. Press the **ENTR** key to accept the new setting or the **EXIT** key to ignore the new setting. The screen will advance to the span voltage setting.
- (e) The **CON_OUT_CH VOLT-S: 900 mV** screen should appear. Repeat step d above to set the Span Voltage Analog Output and while observing the voltmeter, adjust using the increase/decrease keys in the lower portion of the screen to obtain an output voltage indication of 0.900 VDC (\pm 0.003 VDC) on the correct Analog Outputs Channel.
- (f) Press the **ENTR** to accept the new settings. The analyzer will automatically set all digital and analog outputs to the maximum value of the measurement range (i.e., 500 ppb). The corresponding acceptable analog output voltage value should be 1.000VDC (\pm 0.003 VDC).

3.2.6 Optic Test

The optic test function tests the response of the PMT sensor by turning on an LED located in the cooling block of the PMT. The analyzer uses the light emitted from the LED to test its photo-electronic subsystem, including the PMT and the current to voltage converter on the pre-amplifier board. To ensure that the analyzer measures only the light coming from the LED, the analyzer should be supplied with zero air. The optic test should produce a PMT signal of about 2000 \pm 1000 mV. To perform the optic test, follow the procedure in Section 4.8.5 of the TAPI T100 Operation Manual.

This is a coarse test for functionality and not an accurate calibration tool. The resulting PMT signal can vary significantly over time and also changes with low-level calibration.

3.2.7 Electrical Test

The electrical test function creates a current, which substitutes the PMT signal, and feeds it into the

preamplifier board. This signal is generated by circuitry on the preamplifier board itself and tests the filtering and amplification functions of that assembly along with the A/D converter on the motherboard. It does not test the PMT itself. The electrical test should produce a PMT signal of about 2000 ± 1000 mV. To perform the electrical test, follow the procedure in Section 4.8.6 of the TAPI T100 Operation Manual.

3.2.8 Lamp Calibration

An important factor in accurately determining SO₂ concentration is the amount of UV light available to transform the SO₂ into SO₂* (refer to Section 9.1.1 of the Operation Manual). The T100 compensates for variations in the intensity of the available UV light by adjusting the SO₂ concentration calculation using a ratio (**LAMP RATIO**) that results from dividing the current UV lamp (**UV LAMP**) intensity by a value stored in the CPU's memory (**LAMP_CAL**). Both LAMP Ration and UV Lamp are test functions viewable from the instruments front panel. To perform the lamp calibration, follow the procedure in Section 4.8.7 of the TAPI T100 Operation Manual.

3.2.9 Pressure Calibration

The SO₂ analyzer has been set up with temperature and pressure compensation (TPC) turned on. A sensor at the exit of the sample chamber continuously measures the pressure of the sample gas. This data is used to compensate the final SO₂ concentration calculation for changes in atmospheric pressure when the instrument's TPC feature is turned on (refer to Section 10.7.3 of the Operation Manual) and is stored in the CPU's memory as the test function **PRES** (also viewable via the front panel). To perform the pressure calibration, follow the procedure in Section 4.8.8 of the TAPI T100 Operation Manual.

Ensure to use a barometer that measures actual barometric pressure and is currently certified NIST-traceable.

3.2.10 Flow Calibration

The flow calibration allows the user to adjust the values of the sample flow rates as they are displayed on the front panel and reported through COM ports to match the actual flow rate measured at the sample inlet. This does not change the hardware measurement of the flow sensors, only the software calculated values.

To carry out this adjustment, connect an external, sufficiently accurate currently certified NIST-traceable flow meter to the SAMPLE inlet.

Once the flow meter is attached and is measuring actual gas flow, access the **SIGNAL I/O** screen from the **DIAG** Menu, then press **NEXT** until the **FLOW CALIBRATION** screen appears. Press the **ENTR** key and the **ACTUAL FLOW: XXX CC/M** screen should appear, where **XXX** is the analyzer's indicated flow. In the lower left corner of this screen, the flow value will also appear and these values can be adjusted until the displayed flow rate equals the flow rate being measured by the independent flow meter. Press **ENTR** to accept the new value.

4. **FIELD CALIBRATION CONTROL PLAN**

4.1 **PURPOSE AND APPLICABILITY**

- (a) This document describes the overall calibration control strategy to be utilized in the SO₂ gaseous air pollutant measurement program.
- (b) Sections 5 and 6 in this SOP should be referred to for detailed instructions for performing the activities defined under this control plan.
- (c) The purpose of this procedure is to ensure that the output of the field measurement process conforms to accurate standards and is traceable to NIST Standard Reference Material (SRM) or equivalent.

4.2 **DEFINITIONS**

Accuracy - The extent to which a measurement or the average of numerous measurements recorded by a single analyzer agrees with the true value. The difference between the measured value and the true value is defined as the error. For non-zero values, error is expressed as the percent difference ($\Delta\%$) of the measured value compared to the true value. An analyzer, and the resulting measurement data, is considered accurate if the error is less than defined tolerance or control limits.

Assignable Cause - A cause of a fault condition that can be identified and corrected.

Audit - An independent assessment conducted to compare some aspect of performance with a standard for that performance. A performance audit of a continuous gas analyzer incorporates a calibration check utilizing multiple known inputs. A performance audit will always utilize standards and calibration equipment separate from those that are employed in routine network operations.

Audit Calibrator - A device other than the calibrator(s) routinely utilized for conducting monitoring network multi-point calibrations, Level 1 (or Level 2) zero/span checks, and precision checks. An audit calibrator is used only for audits. The audit calibrator must be an EPA-approved transfer standard, in current calibration, capable of producing gas streams at several concentrations equally spaced over the operating range of the analyzer to be audited. These "test gas atmospheres" must be traceable to a primary standard.

Calibration - The process of establishing the relationship between the output of a measurement process and that of a known input.

Calibration Check - The process of determining the relationship between the output of a measurement process and that of a known input in order to ascertain the extent to which it agrees with the desired relationship.

Calibrator - A device used to generate a known input or range of known inputs. A gas dilution calibrator is used to calibrate or check an analyzer in the field. A **reference calibrator** must be in current calibration and capable of producing concentrations over the range of the analyzer to be calibrated or checked. The calibration of a **reference calibrator** must be traceable to a primary standard. For this ambient air monitoring program, the reference calibrator will consist of a Teledyne API T700 gas dilution calibrator, a Teledyne API 701E zero air supply, and an EPA Protocol G-I- certified compressed gas standard containing approximately 50 ppm of SO₂ in oxygen-free N₂.

Control Limit - A value calculated from a sample of test data, and expressed as a hypothetical test value, which defines a limit of random variation of the test data. Control limits are most often a pair of values defining limits of upward and downward variation.

Example: If the designated automatic span value for a given analyzer-calibrator pair is 400 ppb and the calculations indicate that variations of ± 40 ppb or less are attributable to random cause, then the control limits for these spans are:

Upper: 440 ppb

Lower: 360 ppb

Variations outside control limits are attributable to assignable cause. As used in the SOP, "control" and "tolerance" are nearly identical in meaning.

Data Management Center - The location and group where data for a monitoring program or network are processed.

In-Station Calibrator - A calibrator integrated with a continuous monitor at a field monitoring site. The in-station calibrator is typically the source for calibration gases delivered to the analyzer in support of conducting automatic Level 2 checks of calibration drift of a continuous gas analyzer. Such automatic calibration drift checks are informally referred to as "autocal".

Level 1 Check - A dynamic span check at 70-90% full scale, accompanied by a dynamic zero check. The calibration standard(s) used for the check must be NIST-traceable. Results of the check are compared to the tolerance (or control) limit and the analyzer is adjusted if the limit is exceeded.

Level 2 Check - A dynamic span check at 70-90% full scale, accompanied by a dynamic zero check, to verify analyzer performance. A Level 2 check is used to indicate changes in system performance and to demonstrate whether or not the instrument is performing within tolerance or control limits. The calibrator used to generate the test gas inputs for a Level 2 check is typically an in-station calibrator.

Multipoint Calibration - A calibration utilizing (1) multiple known inputs for the initial calibration check to determine linearity and assurance of response; (2) adjustment or readjustment; if required, based on the tolerance or control limits; (3) a final calibration check to confirm linearity and accuracy of response following adjustment or readjustment; and (4) at least three upscale test points and a zero.

NIST - National Institute of Standards and Technology

One-Point Quality Control Check - A check of a monitor's response to a known test gas input concentration of 0.01-0.10 ppm using NIST-traceable calibration standards. Actual input concentrations and analyzer responses are documented, as well as identification of the monitor and calibration standards. No adjustment is made to the monitor. Results of a series of these quality control checks are used to estimate the precision and bias of the data.

Precision - The extent to which any individual value in a set of controlled test data can be expected to agree with the average of the set; the variability of data. Precision is not a measurement to determine "how far" from the true value (accuracy), but rather how scattered are the measurements.

Primary Standard - A method, device, or material having known, stable, measurable, and readily reproducible characteristics.

Random Cause - A cause that cannot be isolated and/or attributed to a correctable condition.

Reference Calibrator - A device other than the in-station calibrator that is used to calibrate or check an analyzer in the field. A reference calibrator must be in current calibration and capable of

producing concentrations over the range of the analyzer to be calibrated or checked. This calibrator must be traceable to a primary standard.

Standard Reference Material - A material (such as bottled gas or permeation tube) that has been certified as a primary standard by NIST.

Tolerance Limit - A non-calculated limit of variation set by contract, regulatory agency, or by judgment based upon experience (e.g., a known input plus/minus some percentage).

Traceability - Refers to written documentation supporting the accuracy, relative to a primary standard, of a method, device, or material, and the data it produces. Documentation must trace the history of calibrations, including dates, methods, and procedures used, back to the relevant primary standard (by number).

Transfer Standard - (Secondary Standard) - A method, device, or material that is calibrated against a primary standard for comparison with a third method, device, or material.

4.3 RESPONSIBILITIES

4.3.1 The Network Operator Shall:

- perform field calibrations and calibration checks in accordance with this Standard Operating Procedure (SOP) and the Quality Assurance Program Plan (QAPP);
- perform all routine quality control checks on monitoring instruments and support equipment in accordance with this SOP and QAPP;
- perform routine maintenance and as-needed field service on all monitoring instruments and support equipment in accordance with this SOP and QAPP;
- maintain proper field documentation of all monitoring program checks and activities and provide monthly secure shipment of monitoring activity records and documentation to Enviroplan's Data Management Department in Fairfield, NJ in accordance with this SOP and QAPP; and

- be aware of and report to the Field Operations Manager or the Project Manager any events or circumstances that require additional technical support or calibration (see Section 4.4).

4.3.2 The Field Operations Manager Shall:

- ensure appropriate stocks of spare parts and consumables are maintained in the network and replenished as necessary to ensure ready availability;
- provide technical guidance and supervision to the network operator on a routine and emergency basis to ensure all monitoring activities, investigative and corrective actions are performed in accordance with this SOP and QAPP; and
- expedite emergency replacement parts and/or equipment delivery to the network operator on an as-needed basis.

4.3.3 The Data Manager Shall:

- ensure the prompt review on the monthly shipments of network field data;
- ensure the review and evaluation of the prior day's raw data each business day and notify appropriate program personnel for resolution of any problems;
- ensure the proper reduction, processing and reporting of all network data in accordance with the procedures outlined in this QAPP; and
- ensure the proper archiving of all network data and data-related documentation.

4.3.4 The Quality Assurance Coordinator Shall:

- ensure the availability of proper calibration equipment and standards and their prompt re-calibration and/or re-certification when so required in accordance with this QAPP;
- ensure the correct and timely performance of independent quality assurance audits on a minimum quarterly basis in accordance with this SOP and QAPP; and

- assist in quality assurance reviews and validation checks on the data to detect any circumstances, action or lack of actions that are at variance with this SOP and QAPP and that may have resulted in invalid data or unacceptable calibration and to accept or reject the data based upon these findings.

4.3.5 The Project Manager Shall:

- review all monitoring program activities on a regular basis and ensure prompt resolution of any problems associated with the network and monitoring program activities, including actions (or lack of actions) which are at variance with this SOP and QAPP;
- ensure that rejected calibrations are redone promptly and that accepted calibration documentation is forwarded to the Data Manager;
- ensure the ready availability of resources required to properly conduct the monitoring program in accordance with this SOP and QAPP;
- review and provide final determination of the acceptability or unacceptability of suspect data in accordance with this SOP, QAPP, and the Quality Assurance Coordinator's findings; and
- ensure final resolution of all Non-Conformance/Corrective Action (NC/CA) events occurring during the monitoring project.

4.4 CONTROL PLAN

4.4.1 Calibrators

- (a) Calibrations, Level-I span checks and precision checks may be performed only with a NIST-traceable reference calibrator that has been acceptably calibrated using NIST-traceable standards within the past six months (\pm two weeks).
- (b) Detailed instructions for performing and documenting calibrations are found in Section 5 of this SOP.

- (c) Perform an audit only with an audit calibrator. The audit calibrator and associated audit gas standard(s) are used solely for QA performance audits and are not used for routine calibration or other routine checks performed on the analyzer. The audit calibrator and associated audit gas standard(s) must be calibrated against NIST-traceable standards within the past six months.

4.4.2 Precision Checks

- (a) Precision checks must be performed with a currently certified reference calibrator and compressed gas standard at a minimum frequency of once every two weeks. Ideally they are performed in conjunction with, but prior to, Level 1 zero/span checks.
- (b) Test gas must pass through all tubing, filters, scrubbers, etc. employed during normal sampling.
- (c) The known input test gas concentration used for precision checks must be within the range of 10-100 ppb.
- (d) All precision checks must be documented on the data form developed for this purpose. See Section 6 for detailed instructions on methods and documentation.
- (e) The percent difference ($\Delta\%$) between the analyzer response and each input concentration is the required precision statistic. If the precision check is rerun after a zero or span adjustment, the original percent difference values (prior to adjustment) may not be changed or superseded by the recheck. The results of the recheck will be documented and included as part of the precision data base.

4.4.3 Level 1 Zero Checks

- (a) Level 1 Zero checks are performed with a currently certified reference calibrator at least once every two weeks. All Level I zero checks must be documented on the data form developed for this purpose. See Section 6 for detailed instructions on methods and documentation
- (b) Zero air must pass through an air drier and scrubber to contain less than 1 ppb of the respective pollutant.

- (c) Following completion of obtaining and documenting the results of an “As Found” (unadjusted) Level 1 zero/span and precision check, evaluate the analyzer’s response to zero air. If it is within the specified tolerance limit (see Table 4-1), adjust the analyzer to the designated zero response as necessary.
- (d) If the “As Found” analyzer Level 1 zero response exceeds the tolerance limit, troubleshoot to determine an assignable cause for the problem before adjusting the analyzer’s response. Possible sources of zero air contamination (filters and/or scrubbers) should be checked before analyzer zero is adjusted. When the zero response is within the tolerance limits, adjustment is complete.
- (e) The site automatic daily zero/span response history should be referenced each time a Level 1 zero/span check is performed, and the results should be compared. Discrepancies between the on-site calibrator and the reference calibrator zero responses greater than ± 5 ppb should be investigated and corrected.

4.4.4 Level I Span Checks

- (a) Level 1 Span checks are performed with a currently certified reference calibrator and compressed gas standard at least once every two weeks. All Level I span checks must be documented on the data form developed for this purpose. See Section 6 for detailed instructions on methods and documentation.
- (b) The input concentration should be 70-90% of analyzer full scale.
- (c) Test gas must pass through all tubing, filters, scrubbers, etc. employed during normal sampling.
- (d) Following completion of obtaining and documenting the results of an “As Found” (unadjusted) Level 1 zero/span and precision check, compute the percent difference ($\Delta\%$) between the analyzer span response and the Level 1 span test gas input concentration. Evaluate the percent difference value with respect to the established control limit (see Table 4-1). If it is within the specified limit, adjust the analyzer to the designated span response as necessary. If the analyzer is adjusted, record the adjusted analyzer response, the associated percent difference, final span setting, and operator's initial on the data sheet.

4.4.5 Multipoint Calibration:

- (a) A multipoint calibration will be performed:
- Upon installation of an analyzer in a field station;
 - After repair or replacement of major components of a malfunctioning analyzer;
 - Prior to removal of an analyzer from a field station, if it is still functioning;
 - When the percent difference of the analyzer's response to a Level 1 span check exceeds $\pm 10.0\%$ (see Table 4-1);
 - When the analyzer's response to a Level 1 zero check exceeds ± 10 ppb (see Table 4-1);
 - When the percent difference of the analyzer's response to any audit point exceeds $\pm 10.0\%$ (see Table 4-1);
 - At a maximum 6 month intervals; and
 - When directed by a supervisor.
- (b) Multipoint calibrations are performed with a currently certified reference calibrator and compressed gas standard. All multipoint calibrations must be documented on the data form developed for this purpose. See Section 5 for detailed instructions on methods and documentation.
- (c) The maximum allowable deviation of the absolute average of analyzer response from known input concentrations is $\pm 15\%$. When analyzer response to calibration gas in a calibration check falls outside this limit, the related ambient data collected will be invalidated.
- (d) The minimum adjustable deviation from a known input concentration is $\pm 5\%$. When analyzer responses during a Level-I span or calibration check fall within this limit, the analyzer need not be adjusted.

- (e) The maximum acceptable deviation for a single-point calibration (i.e., Level-I span check) is $\pm 10\%$. When analyzer response falls outside this limit in a Level I span check, a multi-point calibration must be performed, preceded by an "as-found" (unadjusted) precision and Level-I zero/span check.
- (f) Adjustment following multi-point calibration should always leave the analyzer span response within $\pm 2\%$ of the known span input value (at approximately 70 to 90% full scale); all other upscale analyzer responses should be within $\pm 5\%$ of known input values, and the analyzer zero response within ± 5 ppb of true zero.
- (g) Linear regression analysis of the SO₂ responses shall be performed immediately following multi-point calibration and the observed responses shall not exceed a deviation of $\pm 2\%$ of full scale from the best-fit curve, as defined by the analysis.
- (h) Calculate the percent difference ($\Delta \%$) at each concentration by the following formula:

$$\Delta \% = \frac{(\text{Observed ppm} - \text{Known ppm})}{\text{Known ppm}} \cdot 100$$

- (i) Average the percent difference for all of the test gas concentrations, being careful to retain the correct polarity (positive or negative) of the $\Delta\%$ values during the calculation of average percent difference.

4.6 DOCUMENTATION

- (a) Record the results of all quality control (QC) checks (e.g., multipoint calibrations, Level 1 zero/span checks, precision checks, routine system checks, etc. in ink at the time of the activity on the designated form developed for this purpose (these forms are identified in the following sections of this SOP). Complete all sections of the form. Enter "NA" (not applicable) as necessary. A complete synopsis of the calibration must be neatly and clearly entered in the site logbook on that day's entry. Appropriate clarifying comments, documentation of any maintenance or adjustments, etc., must accompany this synopsis.
- (b) Record the results of all manually-performed analyzer QC checks on the strip chart. The notations on the strip chart should explain each significant deflection of

the recorder pen (e.g., a calibration point, baseline, amp check, adjustment) as well as the beginning and ending times and date of the period during which the analyzer was not sampling ambient air. The notations on the strip chart shall, in toto, provide complete documentation of the QC check.

- (c) If the QC check was a multipoint calibration, label the calibrated analyzer with a calibration sticker showing the analyzer serial number, date of the calibration, and signature of the operator.
- (d) Upon completion of a QC check, distribute documentation as follows:
 - Completed QC field data reporting forms to the Data Management Department.
 - A complete synopsis of the QC check recorded in the on-site logbook entry for that day, which is always retained in the shelter, shall provide the field record.
- (e) Review
 - QC check documentation will be reviewed and approved by designated Data Management Department staff, who will consult with the network technical support personnel as needed to ensure conformance with this SOP and the appropriate procedures.
 - If the QC check results exceed control limits or are otherwise deemed unacceptable, the supervisor must complete a Non-Conformance/Corrective Action (NC/CA) Report (see Section B8 of the QAPP) and the operator of the network shall be notified immediately with the corrective action to be taken. If the QC check was performed by someone other than the network operator, that person shall also be notified. The NC/CA Report will be distributed for review to the Project Manager, Data Manager, Technical Support Personnel, Network Operator, and the Quality Assurance Manager. It will be the responsibility of the Project Manager to assure that proper follow-up corrective action is taken.

TABLE 4-1: SO₂ Analyzer Control Limits

TOLERANCE CHECK	TOLERANCE LIMIT	ACTION	DOCUMENTATION	COMMENTS and/or DATA ACCEPTABILITY
Zero (with reference calibrator)	≤±3 ppb	Adjust as needed <u>AFTER</u> performing "as found" Precision/Zero/Span Check.	P/Z/S-Calibration Form, Control Chart and logbook. Document "as found" and any new analyzer cal. settings and responses.	<u>GOOD PRACTICE</u> : Control between 0 and +5 ppb
	>±5 ppb	Multi-point calibration	As above, plus Multi-point cal. form and NC/CA report	Adjustment of data for zero shift may be evaluated
	>± 10 ppb	Multi-point calibration ("as found"/"as left")	As above	<u>DATA INVALID</u> : (Investigate and correct analyzer response)
Automatic Zero	≤±5 ppb	Check with reference calibrator when approaching limit.	Autocal Zero/Span Chart	<u>GOOD PRACTICE</u> : Control between 0 and +7 ppb.
	>±5 ppb	Check zero response with reference calibrator A.S.A.P.	As above, plus NC/CA report	<u>DATA VALIDITY SUSPECT</u> : Verify analyzer response with reference calibrator.
Level I Span Check (with reference calibrator)	≤±10%	Adjust as needed <u>AFTER</u> performing "as found" Precision/Zero/Span Check.	P/Z/S Calibration form, control chart and logbook. Document "as found" and any new analyzer cal. settings and responses.	<u>GOOD PRACTICE</u> : Control within ±5%
	>±10%	Perform "as found" P/Z/S check followed by multi-point re-calibration.	As above, plus Multi-point cal. form and NC/CA report	As above
	>±15%	Multi-point calibration ("as found"/"as left")	As above, plus NC/CA report	<u>DATA INVALID</u> : (Investigate and correct abrupt analyzer response)
Automatic Span	≤±7%	No action necessary	Autocal Zero Span Chart	Large sudden span shifts bear investigation.
	>±10%	Level I Span Check A.S.A.P.	As above, plus NC/CA report	<u>DATA VALIDITY SUSPECT</u> : Verify analyzer response with reference calibrator.
Multi-point Calibration (with reference calibrator).	<u>Span point</u> within ±2%,	Minimum frequency: every 3 months (or as indicated).	Multi-point Calibration Form and site logbook. Document "as found" P/Z/S analyzer responses, any maintenance, "as left" multi-point responses, and cal. settings.	See Section 5 "Primary Calibration"
	<u>All other points</u> :≤±5% <u>Zero point</u> : Within ±5 ppb	<u>Must meet response criteria (at left) for acceptability</u>		
Audit Span (Independent reference calibrator/ standards)	>±10%	Multi-point re-calibration required	Audit Form and site logbook	Discuss audit results with network operator if possible
	>±15%	As above	As above, plus NC/CA report	<u>DATA INVALID</u> : Corrective action required

5. PRIMARY CALIBRATION

The purpose of a primary calibration is to establish the relationship between actual pollutant concentrations input to the analyzer (in ppm, ppb, ug/m³, etc.) and the measurement system's response (i.e., chart recorder readings, output volts, digital output, etc.). This relationship is used to convert subsequent analyzer response values to corresponding pollutant concentrations until superseded by a later calibration of the analyzer.

5.1 EQUIPMENT AND MATERIALS

- (a) TAPI T100 Operator Manual
- (b) A reference (NIST-traceable) gas dilution calibrator (TAPI T700 calibrator or equivalent).
- (c) Clean, dry zero air source ("TAPI 700E" zero air supply or equivalent).
- (d) Certified EPA Protocol G-1 compressed gas standard containing approximately 50 ppm SO₂ referenced to NIST-SRM.
- (e) Dual-stage, stainless-steel, high-purity gas regulator (CGA 660).
- (f) FEP Teflon tubing and stainless steel or Teflon compression fittings (for effecting leak-free interconnections for gas delivery between the zero air supply, compressed gas standard, dilution calibrator and analyzer sample inlet).
- (g) Certified voltmeter (NIST-traceable) with a minimum resolution of 4 digits and a minimum accuracy of ± 0.001 VDC (e.g., Fluke 287 or equivalent).
- (h) Texas Instruments T.I. 60 calculator (or equivalent).
- (i) SO₂ Calibration Form (Form 5-1). Example at end of this SOP.

5.2 FREQUENCY

- (a) Initial installation.
- (b) Relocation.
- (c) Component failure that might affect analyzer's calibration.
- (d) Level 1 zero/span drift limits are exceeded (see Table 4-1).
- (e) Failure of a performance audit (see Table 4-1).

- (f) At least once every six months, even if Level-I zero/span and precision checks show analyzer to be well within specified control limits.

5.3 ANALYZER

- (a) Calibrations will be performed on-site.
- (b) Analyzer will be in its normal sampling mode and test gas atmospheres will pass through all filters, scrubbers, conditioners, and all other components used during normal ambient sampling and as much of the ambient air delivery system as is practicable.
- (c) Unless the calibration data are obtained to assess “As Found” (unadjusted) analyzer response, all maintenance and any operational adjustments to the analyzer should be completed prior to running the calibration points. If the calibration is being performed on a properly-functioning analyzer that is currently producing data for the monitoring program, an “As Found” (unadjusted) Precision/Zero/Span (Level-I) check **MUST** be performed first, and the unadjusted analyzer response documented (refer to Section 6 in this SOP for detailed procedures for performing Level 1 zero/span and precision checks).

5.4 TEST GAS CONCENTRATIONS

Test gas concentrations delivered to the analyzer for a multipoint calibration will consist of a “zero” concentration (i.e., ≤ 1 ppb of the pollutant gas present in the gas stream) and at least four upscale test gas concentrations equally spaced over the analyzer's operating range. The highest SO₂ test gas input concentration should fall within 70% ~ 90% of the analyzer's full scale operating range.

5.5 MULTI-POINT CALIBRATION PROCEDURE

- (a) Fill out the heading information on the SO₂ Calibration Form (see Form 5-1 at end of this SOP) with the models and serial numbers of the calibrator and zero air generator used, analyzer model and serial number, compressed gas standard cylinder I.D. number, concentration (ppm), pressure, and certification dates, the date of the calibration and other information pertinent to the calibration process.
- (b) Allow the calibrator to warm up properly as described in the manufacturer's instruction manual. Purge the gas delivery system of the compressed SO₂ gas standard to be used (see Step (c) below).
- (c) The gas cylinder's two-stage, stainless steel regulator must always be purged prior to use for calibration to ensure it contains only gas from the cylinder-NOT ambient air. It is highly recommended that an initial series of purges be done 24 hours

prior to use. A second series of purges is recommended immediately prior to use. Purging is accomplished by either of two methods:

Regulator Purge Method No. 1: After the regulator is securely tightened on the cylinder, (ensure cylinder valve is closed), attach a vacuum pump to the regulator outlet using airtight fittings. Open the regulator output valve, and use the pump to evacuate the regulator to approximately -26 inches of Hg, as indicated on the regulator's output gauge. Close the regulator output valve, shut off the pump, and slowly open the cylinder valve to allow the regulator to become fully pressurized with the cylinder gas contents. Close the cylinder valve, open the regulator outlet valve, and repeat the evacuation process of the regulator, using the vacuum pump. This procedure should be repeated at least three times. The 1/8" tubing terminating in the stainless steel "quick-connect" fitting (which mates with the TAPI T100 inlet port) may now be attached to the regulator output fitting. After the tubing and quick-connect fitting are attached, open both the secondary valve of the regulator and the cylinder valve, and make the connection to the calibrator gas inlet port. Adjust regulator output pressure to read approximately 30 PSI, as indicated by the regulator output pressure gauge.

Regulator Purge Method No. 2: Securely affix the regulator to the cylinder. Attach a 1/8" (O.D.) Teflon line (terminating in a 1/8" quick-connect fitting) to the regulator output fitting. Open the cylinder valve and allow the regulator to fully pressurize with gas from the cylinder. Adjust the regulator output pressure to 30 PSI, as indicated on the regulator output pressure gauge. Close the cylinder valve and open regulator output valve fully (the regulator will stay pressurized, as the 1/8" quick-connect fitting on the outlet line will not allow gas flow until the stem tip is depressed). Depress the stem tip of the "quick-connect" fitting against a convenient surface, allowing the gas in the regulator to slowly bleed off. Cease this gas flow (stop depressing "quick-connect" stem tip) when the output pressure gauge reading falls to 10 PSI (do NOT allow the outlet pressure to drop to 0 PSI). Re-pressurize the regulator fully by opening cylinder valve, closing it afterwards. Repeat the "bleeding" process by depressing the quick-connect valve stem tip. Reiterate this process 12-24 times, then make connections as usual to the gas dilution calibrator gas channel inlet port. Open the cylinder valve for gas flow.

Once the regulator has been purged, it should be left on the cylinder. The alternate procedure may then be employed (6-12 purges) just prior to any future use. The regulator and cylinder valves should always be fully closed unless in use. The regulator should remain pressurized at all times. **Assure gas cylinder pressure is greater than 100 PSI before use. Cylinders containing less than 100 PSI must not be used.**

- (d) If the monitoring system is tied into a data collection system, provide the proper status information indicating that a calibration is being performed and that the data are to be excluded from the ambient measurements data base.

- (e) **Prior to conducting the multi-point calibration, and prior to making any adjustments to a functional analyzer currently producing data for the ambient monitoring program, a precision and Level-I zero/span check (“P/Z/S” check) must first be performed (see Section 6 of this SOP).** This practice allows evaluation of analyzer "As Found" (unadjusted) response. If, however, the multi-point calibration is being performed immediately following major analyzer repairs or initial analyzer startup, an “As Found” P/Z/S check is not necessary.

If the "As Found" P/Z/S check zero response exceeds ± 10 ppb, or if the "As Found" P/Z/S check span response exceeds $\pm 15\%$ deviation from the known span input value, the analyzer should be subjected to a complete "As Found" multi-point calibration (i.e., obtain all multi-point calibration responses prior to making any adjustment to the analyzer). This unadjusted analyzer response data will be helpful in assessing historical data validity in such cases. "As Found" multi-point calibrations should be clearly labeled as such on Form 6-1. They are performed exactly as iterated in this section, with the following exceptions:

- No adjustments are made to the analyzer.
- All "As Found" multi-point calibration responses will be clearly labeled "As Found".

Assuming an "As Found" multi-point calibration was required, after it is completed, investigative and corrective action should take place to determine and correct the cause(s) for the excessive analyzer response drift. An NC/CA report must be completed to document the findings. After any problems are resolved, an "As Left" multi-point calibration must be performed, with adjustments made as necessary to the analyzer so that the "As Left" responses meet the acceptability criteria stated in Step (i) below. All "As Left" multi-point calibration documentation must be clearly labeled as such.

- (f) Calculate the calibrator flow settings needed for the calibration system to produce the desired upscale concentrations of SO₂ using Equation 1. At least four SO₂ upscale test gas concentrations will be used in addition to zero. The upscale test gas concentrations will be in the following ranges:

80 - 100 ppb
 200 - 250 ppb
 300 - 350 ppb
 400 - 450 ppb

$$[SO_2]_{out} = \left[\frac{F_G}{F_G + F_D} \right] \cdot C_{cyl} \quad \text{Equation 1}$$

Where:

$[\text{SO}_2]_{\text{out}}$ = the desired SO₂ concentration (ppm)
 C_{cyl} = the SO₂ concentration in the calibration gas cylinder (ppm)
 F_G = the flow of SO₂ gas from the calibrator gas channel (scc/min)
 F_D = the flow of dilution air from the calibrator air channel (scc/min)

Note: Use the current calibration curve of the gas dilution calibrator (as determined at six month intervals by the Enviroplan QA laboratory) to determine the appropriate diluent air channel and gas channel "display" settings necessary to produce the flow rates calculated above.

- (h) Set the calibration system to produce "zero" air: connect the output of the zero air generator to the "Air" input of the calibrator. Connect the output of the calibrator to the SAMPLE inlet of the analyzer through as much of the sample pneumatics as practical. Be certain that all filters and scrubbers usually in the system are included. Also be certain that the calibrator is always set to produce a minimum of 1500 cc/min (1.5 standard liters per minute) of total flow so that it will exceed (by a minimum of 25%) the sample demand of the analyzer. Vent the excess calibrator output flow with a manifold or "tee" fitting with one leg of the "tee" left open to the exhaust system of the shelter. Keep the delivery pressure of the calibration gas to the analyzer as close to atmospheric pressure as possible. Do not subject the analyzer to positive or negative pressures of more than 0.5" H₂O. When the analyzer responses have stabilized, note the output response for SO₂ in volts, as well as the corresponding ppm values indicated by the data acquisition system, or "DAS", and recorder % full scale response.

Evaluate the initial analyzer zero response in accordance with the criteria set forth in Step (e) above and Table 4-1, and ensure appropriate "As Found" analyzer response checks have been obtained prior to making any analyzer adjustments. Assuming satisfactory completion of any "As Found" checks, document the analyzer's initial calibration settings in the designated spaces provided on Form 6-1, and proceed to adjust the instrument's zero and span response as follows:

1. Set the expected SO₂ span gas concentrations. Confirm that the instrument is set for single (SNGL) range mode with a reporting range span of 500 ppb. In the Main screen, press the **CAL** key which causes the analyzer to prompt for the expected SO₂ span concentration. The SO₂ span concentration automatically defaults to 450 ppb. Change this value to the actual concentration of the span gas by pressing the key under each digit until the expected value appears. Press **ENTR** to accept the new setting and return to the previous display.
2. Press the **TST>** button until the display shows the **SO₂ STB** test function. This function calculates the stability of the SO₂ measurement. Deliver zero

gas to the sample port at the rear of the instrument and wait until **SO₂ STB** falls below 0.5 ppb. This may take several minutes.

3. Press the **CAL** pushbutton again to return to the “Calibration” Menu. Press the **ZERO** key and then press **ENTR** to change the **OFFSET & SLOPE** values for the SO₂ measurements. Record the stable zero response observed from on the analyzer display, analyzer output voltage (in Volts), and DAS (in ppb) in the designated spaces provided in the “SO₂ RESPONSE” section of the multi-point calibration form.
4. Allow span gas to enter the sample port at the rear of the instrument. The value of **SO₂ STB** may jump significantly. Wait until it falls back to below 0.5 ppb. This may take several minutes. The **SPAN** key now appears during the transition from zero to span. Press the **SPAN** key. Press **ENTR** to change the **OFFSET & SLOPE** values for the SO₂ measurements. Record the stable span response observed from on the analyzer display, analyzer output voltage (in Volts), and DAS (in ppb) in the designated spaces provided in the “SO₂ RESPONSE” section of the multi-point calibration form. Press **EXIT** to return to the main **SAMPLE** display.
5. Set the Display to show the **STABIL** test function. This function calculates the stability of the SO₂ measurement. All calibration gas diluted to proper concentration for Midpoint 1 to enter the sample port. Wait until **STABIL** falls below 0.5 ppb. This may take several minutes. Record the SO₂ reading as displayed on the instrument’s front panel. Record the stable midpoint response observed from on the analyzer display, analyzer output voltage (in Volts), and DAS (in ppb) in the designated spaces provided in the “SO₂ RESPONSE” section of the multi-point calibration form. Press **EXIT** to return to the main **SAMPLE** display.
6. Repeat step 4 for each of the additional midpoints.
7. When no further adjustments are necessary, record the final, stable measurement system response to both the zero and span test gas concentrations as indicated by the analyzer output voltage (in volts) and DAS response (in ppb) in the designated spaces provided in the “SO₂ RESPONSE” section of the multipoint calibration form. Calculate the percent difference ($\Delta\%$) of the SO₂ measurement system’s response to the span gas input concentration using the following equation (where the “observed ppm” concentration is taken from the DAS). Verify that the $\Delta\%$ value is within $\pm 2\%$ of the corresponding span input concentration. Record the percent difference (rounded to the nearest tenth of a percent) in the same section of the multi-point calibration form.

$$\Delta \% = \frac{(\text{Observed ppm} - \text{Known ppm})}{\text{Known ppm}} \cdot 100$$

- (j) **SO₂ Linear Regression Calculation:** After acceptable calibration results are achieved, use the T.I.-60 (or equivalent) calculator to perform a linear regression analyses on the SO₂ analyzer responses. Use the SO₂ ppm known (input) concentrations from Steps (h), (i) and (j) above as the "X" factors for the regression analysis, and the corresponding DAS-indicated SO₂ ppm responses (recorded in the "SO₂ RESPONSE" section of Form 5-1) as the "Y" factors of the regression analysis. This will yield an equation in the form of Y = mX + b, where "m" is the slope and "b" is the intercept, for the SO₂ response.

Record the slope, intercept, and correlation coefficient in the designated spaces provided on the calibration form. Check the linearity of the observed SO₂ responses against the linear regression curve. Each point shall not exceed a deviation of $\pm 2\%$ of full scale when compared to the corresponding value obtained from the curve in order to qualify for acceptable linearity. If any point deviates from the curve by more than $\pm 2\%$ of full scale, then re-run the point(s) and perform a new linear regression analysis for the SO₂ analyzer response.

- (k) Obtain and record on the calibration form the analyzer **SLOPE** and **OFFSET** calibration factors (analogous to zero and span settings) entered into the Model T100 during the calibration process. To obtain this information, select the **CAL DATA** screen from the Main Menu. This will enable the display of the calibration factors.

If an "As Left" calibration form was utilized, ensure all headings, data columns and sections have been completely filled out, including the initial and final, adjusted values of the SO₂ analyzer calibration factors (i.e., initial and final **SLOPE** and **OFFSET** factors). Clearly label all completed calibration forms "As Found" or "As Left", as applicable.

- (l) Conduct a manually-initiated span/zero check of the analyzer using the in-station calibrator (used for daily automatic zero/span checks). Verify the zero and span response closely agrees with the observed analyzer zero response obtained during the calibration
- (m) Restore the monitoring system to normal ambient sample mode: disconnect the sample line from the reference calibrator's gas delivery line and re-connect it to the sample intake manifold. If the monitoring system is tied into a data collection system, provide the proper status information indicating that valid data is again being collected.
- (n) Neatly record a complete synopsis of the calibration data (including any adjustments made) in that day's site logbook entry.

5.6 DOCUMENTATION

- (a) Completed SO₂ Multi-point Calibration Forms are sent to the Enviroplan Consulting Data Management Department for review (include with regular monthly shipments of field data).
- (b) Enter all results in site logbook in a neat, concise, and comprehensible format. Include any and all adjustments. This provides the permanent on-site record.
- (c) See Section 4.6 for additional documentation requirements.

6. LEVEL 1 ZERO/SPAN AND ONE-POINT QUALITY CONTROL CHECK PROCEDURES

Data Quality Assurance requirements set forth in 40 CFR Part 58, Appendix A stipulate that one-point quality control checks are required to be made on automated gaseous pollutant analyzers used in air quality monitoring applications. The results of these checks are used as indicators of the quality of the monitoring data reported. “Level I” zero/span checks are made using NIST-traceable calibration standards and provide periodic, authoritative assessments of the conformance of an analyzer’s response with current calibration data.

The one-point quality control check requirement will be met by challenging the analyzer at a known input test gas concentration. The one-point quality control test gas concentration will be within the range of 10-100 ppb. The percent difference (Δ %) between the actual concentration indicated by the SO₂ measurement system and the known concentration of each one-point quality control check gas concentration is used to assess the precision and bias of the monitoring data.

A Level 1 zero/span check will be performed in conjunction with scheduled precision checks. The Level 1 check consists of a zero check gas and one-point span check gas of known concentration within the range of 70 to 90% of the analyzer’s full scale measurement range. The Level-I zero and span checks provide a method by which analyzer accuracy and calibration drift can be assessed and controlled. The percent difference (Δ %) between the actual concentration indicated by the SO₂ measurement system and the known span input concentration is used to assess the degree of calibration control (or drift) of the monitoring system.

Collectively, these checks are informally referred to as “P/Z/S” checks. This check will be automatically initiated by the digital acquisition system every two weeks. The procedure for performing a manual P/Z/S check is described in the following sub-sections.

6.1 EQUIPMENT

- (a) TAPI T100 Operation Manual
- (b) Certified gas dilution calibration system (e.g., TAPI T700 calibrator with “TAPI 700E” Zero Air Supply, or equivalent)
- (c) Certified (EPA Protocol G-1) cylinder containing approximately 50 ppm SO₂ in N₂ referenced to NIST-SRM (used w/gas dilution calibrator and zero air generator).
- (d) Dual-stage, stainless-steel, high-purity gas regulator (CGA 660).
- (e) Certified voltmeter (NIST-traceable) with 4-digit display and minimum accuracy of ± 0.001 VDC (e.g., Fluke 287 or equivalent).

- (f) FEP Teflon tubing and stainless steel or Teflon compression fittings (for effecting leak-free interconnections for gas delivery between the zero air supply, compressed gas standard, dilution calibrator and analyzer sample inlet).
- (g) Texas Instruments T.I.-60 calculator or equivalent.
- (h) SO₂ Calibration Form (Form 5-1). An example of this form appears at the end of this SOP.

6.2 FREQUENCY

- (a) At least once every two weeks (automatically initiated by DAS).
- (b) When automatic daily zero/span check ("autocal") control limits are exceeded (see Table 4-1).
- (c) Prior to performing multi-point calibrations on functional analyzers currently producing data for an ambient air monitoring program.

6.3 DEFINITIONS

For this procedure, the following definitions apply.

- (a) **One-Point Quality Control Check** - For this monitoring program, a one-point quality control check will consist of a dynamic response check of the analyzer at a NIST-traceable test gas input concentration within the range of 10-100 ppb. The results of all one-point quality control checks are used to compute precision and bias of the data. A one-point quality control check must precede any adjustment to the analyzer.
- (b) **Zero Check** - a dynamic response check of the analyzer to a "zero" air gas stream (i.e. contains less than 1 ppb of the respective pollutants).
- (c) **Level-I Span Check** - a dynamic response check of the analyzer to a NIST-traceable test gas input concentration at 70-90% of full scale. This, together with the zero check, is used to evaluate the current calibration drift of the analyzer, and to determine the need for any adjustments.

6.4 PROCEDURE: LEVEL 1 ZERO/SPAN AND PRECISION CHECKS

IMPORTANT Be aware of the difference between Calibration where adjustments are made to the analyzer and Calibration Check (P/Z/S). Pressing the ENTR button during the following procedure re-calculates the stored values for OFFSET and SLOPE and alters the instrument's calibration. If you wish to perform a calibration CHECK, do not press ENTR. This procedure is described in Section 6.3 of the TAPI T100 Operation Manual.

- (a) Allow the calibrator to warm up properly as described in the Operation Manual. Make appropriate gas delivery line connections from the zero air source to the calibrator (all materials must be FEP Teflon or stainless steel). Connect the output of the calibrator to the sample inlet of the analyzer. Ensure a "tee" fitting (with one leg left open to the atmosphere) vent is incorporated at the connection of this line to the sample inlet so that gas is delivered to the analyzer at or near atmospheric pressure. Make certain the sample inlet connection incorporates as much of the sample delivery train as is practicable, including any and all filters or scrubbers normally used. Purge the gas delivery system of the SO₂ standard to be used. (See Section 5, Step (c) for purge procedures.) It is highly recommended that the gas regulator and delivery line be attached to the gas standard 24 to 48 hours prior to use. The regulator should be subjected to a series of purges at this time and at least one additional series of purges prior to use. Ensure gas cylinder pressure is greater than 100 PSI. **Do not use a cylinder containing pressure less than 100 PSI.**
- (b) Fill out the heading information on the SO₂ Calibration Form (see Form 5-1 at end of this SOP) with the models and serial numbers of the calibrator and zero air generator used, analyzer model and serial number, compressed gas standard cylinder I.D. number, concentration (ppm), pressure, and certification dates, the date of the calibration and other information pertinent to the calibration process. Fill out the header information called out on Form 6-1. Access the analyzer's calibration factors in the **CALDAT** menu and record the analyzer's current **SLOPE** and **OFFSET** calibration settings in the designated spaces provided on Form 6-1.
- (c) Supply the necessary status information to the datalogger to exclude the SO₂ test data from the data base.
- (d) Use the following equation to calculate the designated test gas concentrations for SO₂ (for one-point quality control point, 10 to 100 ppb; for Level 1 span point, 350 to 450 ppb) (**NOTE:** Select flow rates such that $F_D + F_{NO}$ exceeds analyzer flow rate by at least 25%).

$$[SO_2]_{out} = \left[\frac{F_G}{F_G + F_D} \right] \cdot C_{cyl} \quad \text{Equation 1}$$

Where:

- $[SO_2]_{out}$ = the desired SO₂ concentration (ppm)
 C_{cyl} = the SO₂ concentration in the calibration gas cylinder (ppm)
 F_G = the flow of SO₂ gas from the calibrator gas channel (scc/min)
 F_D = the flow of dilution air from the calibrator air channel (scc/min)

- (e) Use the current calibration curves of the gas and air mass flow controllers in the gas dilution calibrator (as determined at 6-month intervals by the Enviroplan Consulting Q.A. Lab) to determine the appropriate diluent air channel and gas channel "display settings" needed to effect the flow rates calculated in Step (d) above.
- (f) Generate a Level 1 Zero test gas concentration, making sure F_D exceeds the analyzer sample flow rate by at least 25%. Scroll the <TST TST> keys to display the **STABIL** test function. Allow the analyzer response to stabilize. Wait until **STABIL** is below 0.5 ppb. This may take several minutes. Record the zero response of the SO₂ measurement system as observed on the analyzer's output voltage (in volts) and the DAS response (in ppm). Record these responses in the designated spaces provided in the "As Found SO₂ Response" data section of the precision/zero/span check form. **MAKE NO ADJUSTMENTS AT THIS TIME BY PRESSING THE ENTR KEY!**
- (g) Generate an SO₂ precision test gas concentration within the range of 80 to 100 ppb. (Again, ensure the calibrator's total flow rate exceeds the analyzer's sample flow rate by at least 25%) Scroll the <TST TST> keys to display the **STABIL** test function. Allow the analyzer response to stabilize. Wait until **STABIL** is below 0.5 ppb. This may take several minutes. Record the zero response of the SO₂ measurement system as observed on the analyzer's output voltage (in volts) and the DAS response (in ppm). Record these responses in the designated spaces provided in the "As Found SO₂ Response" data section of the precision/zero/span check form. **MAKE NO ADJUSTMENTS AT THIS TIME BY PRESSING THE ENTR KEY!**
- (h) Repeat as in (g) for an SO₂ Level 1 Span test gas concentration of approximately 70-90% full scale (i.e., 350 to 450 ppm). Record the stable measurement system responses as described in Step (f). **MAKE NO ADJUSTMENTS AT THIS TIME BY PRESSING THE ENTR KEY!**
- (i) Calculations:
- (1.) Calculate the percent difference ($\Delta\%$) for each of the three upscale SO₂ response points obtained in Steps (g), (h) and (i) above according to the formula:
- $$\Delta \% = \frac{(\text{Observed ppm} - \text{Known ppm})}{\text{Known ppm}} \cdot 100$$
- (2.) Record the percent difference results (rounded to the nearest tenth of a percent) in the designated spaces provided in the "As Found SO₂ Response" section of Form 5-1.

6.5 CONTROL LIMITS FOR LEVEL 1 ZERO/SPAN CHECKS

6.5.1 Evaluate “As Found” Results

The control limits for “As Found” (unadjusted) Level 1 zero/span checks responses are as follows:

- Zero Response: $\leq \pm 5$ ppb
- Span Response: $\Delta\% \leq \pm 10\%$ (compared to the known span gas input concentration).

If all “As Found” (unadjusted) responses are within the specified control limits, minor adjustments to the analyzer’s **SLOPE** and/or **OFFSET** settings may be made to keep the analyzer’s response well within the specified control limits. These adjustments may be warranted as a strategy for providing a high degree of assurance that the measurement system’s response will remain within the control limits going forward. Any such adjustments, however, must be immediately followed by performance and documentation of an “As Left” (adjusted response) Level 1 zero/span check. Procedures for accomplishing this are presented in Section 6.5.2 below.

If any of the control limits are exceeded, a multi-point calibration is necessary (see Section 5).

Furthermore, if the “As Found” Level 1 span response $\Delta\%$ exceeded $\pm 15\%$, or if the “As Found” Level 1 zero response exceeded ± 5 ppb, a complete unadjusted multipoint calibration should be performed and documented prior to performing an adjusted calibration. In any event, it is mandatory that “As Found” (unadjusted) precision, zero and span responses be obtained and documented prior to any adjustments taking place.

Before making any adjustment to the analyzer (either zero or span), however, it is prudent to examine all available information and make sure the analyzer calibration has really drifted. Subtle malfunctions of the calibrator can cause unnecessary adjustment of an analyzer and much unnecessary grief. This can be avoided by taking the extra time to be careful in performing Level 1 Zero/Span and Precision checks.

- (a) Review the previous Level 1 zero/span and One-Point Quality Control Check results to see how much the analyzer has drifted since the last check. If excessive change (more than $\pm 10\%$) has occurred, there may be a problem with the analyzer or calibrator. Investigative actions should be undertaken to assure both instruments are operating properly. **NOTE: If the calibration system is found to be the source of the problem, the precision/zero/span check just completed is invalid.**
- (b) Refer to the data logger autocal reports for the analyzer and carefully examine the autocal results since the last Level-I Span Check. If the analyzer has drifted excessively, the trend should be apparent.

- (c) Double check all calculations. Make sure the dilution calibrator flow calibration data and gas standard analysis you are using are current.
- (d) Carefully examine all plumbing for dirt, leaks, crimps or other potential causes of erroneous readings.
- (e) Check the analyzer's operating status readouts and compare these to historical records and the manufacturer's stated normal ranges. If a significant change is evident, the analyzer may have a problem. (Investigate to verify. Check the analyzer "Diagnostics" menu and Chapter 6 -"Troubleshooting"- in the manufacturer's Instruction Manual as an aid to resolving any operational problem with the analyzer.) Also, check the analyzer's sample line and particulate filter. Changing the filter element might solve the problem and eliminate the need for analyzer adjustment.
- (f) Record all investigative findings and associated corrective actions (if any) in the field station log for future reference.

6.5.2 Analyzer Adjustments

- (a) As previously stated, the control limit for unadjusted Level 1 span check results are $\pm 10\%$ of designated test gas concentrations. Similarly, the control limit for unadjusted zero responses are ± 5 ppb. If these limits are exceeded, a full multi-point (adjusted response) calibration of the analyzer is necessary (refer to Section 5 of this SOP).

NOTE: If the unadjusted span response exceeded $\pm 15\%$, or the unadjusted zero responses exceed ± 5 ppb, a complete unadjusted multi-point calibration response should be performed prior to performing investigative actions to establish assignable cause for such drift, corrective actions and subsequent re-calibration. Additionally, an NC/CA Report Form must be completed by the network operator (see Section C of the QAPP).

- (b) If the percent differences for all span responses are within $\pm 5\%$, there is little need to make a span adjustment. If span response is $> \pm 5\%$, but $\leq \pm 10\%$, verify all calculations, settings, and proper operating status prior to making any adjustments. Adjust the analyzer span setting to obtain a reading within $\pm 5\%$ (refer to Step (h) in Section 5.5 under "Multipoint Calibration Procedure" for correct span adjustment procedure).
- (c) If an adjustment to the analyzer zero response is desired, or if a span adjustment was necessary in Step (b) above, repeat the zero check. The control limit for zero response is ± 10 ppb. If the initial "As Found" Level 1 zero check response was within this control limit, adjust the zero setting as needed to maintain acceptable zero response going forward (refer to Step (g) in Section 5.5 under the

“Multipoint Calibration Procedure” for instructions on zero adjustment). Recommended good practice is to maintain zero response within ± 3 ppb.

- (d) Repeat and re-verify the adjusted span and/or zero responses as necessary until both responses are satisfactory. Record the final “As Left” (adjusted) values for the measurement system zero and span responses as described in Step (f) above for the analyzer output voltage and DAS indications in the designated “As Left SO₂ Response” spaces provided on Form 5-1.
- (e) Finally, access the **CAL DATA** menu screen and record the final “As Left” (adjusted) values for the **SLOPE** and **OFFSET** settings in the designated spaces provided on Form 5-1.
- (f) Restore the monitoring system to normal ambient sample mode: disconnect the sample line from the reference calibrator’s gas delivery line and re-connect it to the sample intake manifold. If the monitoring system is tied into a data collection system, provide the proper status information indicating that valid data is again being collected.
- (g) Enter date, time, and operator’s initials on the strip chart at end of the P/Z/S check. Ensure all significant traces and adjustments are fully documented on strip chart. Neatly record a complete synopsis of the P/Z/S check results (including any adjustments made) in that day's site logbook entry.

6.6 DOCUMENTATION

- (a) Enter all results and activities in the site logbook. This provides the permanent on-site record.
- (b) SO₂ Calibration Form (Form 5-1) sent to Enviroplan Consulting’s Data Management Department on a monthly basis.

7. ROUTINE OPERATION

During each scheduled site visit, the analyzer and support equipment (calibrator, datalogger, shelter temperature control system, sample train, etc.) should be inspected to verify proper operation. A thorough inspection of instrument operations will help locate potential problems before they have substantive effect and therefore help ensure proper instrument function between site visits. Routine site visits shall be conducted at a minimum frequency of once per week. Two visits per week should be conducted in the event that telephone service to the site is not available to allow remote review of the data. Each site inspection should include the following:

7.1 DATA LOGGER

- (a) Check the logbook for instrument status noted during the previous site visit.
- (b) Review the data logger record of all analyzer parameters back to the most recent, previous data logger inspection.
 - (1) verify that automatic daily zero/span checks are within control limits.
 - (2) verify that the characteristics of the data appear normal and reasonable.
 - (3) make sure that the data logger time correlates with the actual time
- (c) During each site visit, record the date, current local standard time (LST), instrument status, and operator initials.
 - Date
 - Time check (LST) and any adjustments made to correct discrepancies relative to current LST and/or date.
 - Instrument zero check responses (except for auto-cal traces)
 - Instrument span check responses and associated known input test gas concentrations (except for auto-cal traces)
 - For segments containing test traces, identification of the type of check performed (including designating “As Found”/”As Left” responses, as applicable).
 - Periods of time that service or maintenance were performed
 - Site and network names
 - Unusual conditions or events (e.g., meteorology, industrial activity, fires, and shelter temperature problems) that could affect data interpretation.

- Any adjustments made.

7.2 ANALYZER

- Perform and document all checks of analyzer internal operating status indications called out on the site check form (Form 7-1). Example form at end of this SOP.
- Check all electrical and pneumatic connections.
- Listen for unusual noises which might indicate a developing problem (e.g., pump going bad).
- Ensure the in-line sample particulate filter is replaced every two weeks, or more frequently if inspection warrants. Use only FEP Teflon membrane filters for this purpose.

7.3 OTHER SUPPORT EQUIPMENT

- Calibrator - Check all connections and verify correct current time and date display. Verify all status indications are correct. Verify that calibrator, analyzer and datalogger-indicated current time and date match.
- Sample delivery system and lines - Check the system for integrity, condensation, and cleanliness. If there is any liquid (condensed) water present in any components of the sample air delivery system, document the finding in the "Comments" section of Form 7-1 and use a clean, lint-free, absorbent cloth and/or compressed air to thoroughly dry the affected components. Consult the Field Operations Supervisor or Project Manager to determine the need for and appropriate methods to prevent a recurrence. **SO₂ data will be invalidated for the 24-hour period preceding the detection of liquid condensate in the sampling train.**
- Shelter temperature and control equipment- Inspect all other equipment (heaters, air conditioners, etc.) for proper operation. Check and log site temperature (minimum and maximum) and reset min/max thermometer.

7.4 DOCUMENTATION

- Fill out all of site check Form 7-1 completely.
- Enter all activities performed in the site logbook. An entry must be made each time the site is entered. If all operations appeared normal, the logbook entry would contain at a minimum: Date, time of arrival (LST), minimum/maximum shelter temperature, monitoring system status (e.g., "all operations normal"), time

of departure (LST) and operator's signature. All entries must be clear, complete, specific, legible, and accurate so that they can be used by other people at other times to evaluate all monitoring program field activities and data validity. Any NC/CA events, including associated investigative and corrective actions, should be clearly and concisely documented.

8. PREVENTIVE AND CORRECTIVE MAINTENANCE

In order to ensure the reliable operation of monitoring equipment, and a high degree of valid data capture, a preventive maintenance program is essential. For the SO₂ measurement system, preventive maintenance is applicable to the analyzer and related support equipment. Preventive maintenance activities are based on the guidance contained in the manufacturers' operating manual and Enviroplan Consulting's cumulative experience in conducting ambient air monitoring programs.

All maintenance performed must be entered in a chronological format in the site logbook and instrument maintenance log (see Form 8-1 at the end of this SOP). The instrument must be identified by make, model and serial number. Each entry must be dated and signed by the network operator.

8.1 ANALYZER

8.1.1 Analyzer Preventive Maintenance

Table 8-1 in this section presents a schedule of preventive maintenance for the TAPI T100 SO₂ analyzer. This schedule is based on the following:

- The guidance contained in the manufacturer's Instruction Manual (refer to Chapter 5, "Preventive Maintenance");
- Evaluation of analyzer operating status indications, analyzer response check trends and characteristics of the analyzer output signals obtained during response checks (e.g., stability, evidence of noise, etc.); and
- The field supervisor's and local operator's judgment concerning environmental conditions at a particular site and the analyzer history.

Analyzer Preventive Maintenance Items:

- (a) The sample particulate filter (i.e., 49 mm diameter, 5 micron, Teflon membrane filter in the sample line) should be checked and replaced at least every two weeks **after** the precision check and "As Found" Level-I zero/span check is performed.
- (b) The analyzer fan filter, thermoelectric cooler fins and analyzer cooling fans should be visually inspected and cleaned as necessary every three months. These tasks may have to be performed more often depending upon site conditions (e.g., excessively dirty surroundings).
- (c) The sample flow through the analyzer should be checked every six months prior to performing a multi-point calibration. Sample flow checks are useful for monitoring the actual flow of the instrument, to monitor drift of the internal flow measurement.

A decreasing, actual sample flow may point to slowly clogging pneumatic paths, most likely critical flow orifices or sintered filters. Use a separate, calibrated flow meter capable of measuring flows between 0 and 1000 cm³/min to measure the gas flow rate through the analyzer. For this procedure, do not refer to the built in flow measurement shown in the front panel display screen. The sample flow measured with the external flow meter should be 650 cm³/min \pm 10%. To perform a sample flow check, follow the sample flow check procedure in Section 8.3.7 of the Operation Manual.

- (d) Preventive maintenance for the analyzer flow control capillary should be performed every six months (typically, prior to performing an adjusted multi-point calibration).
- (e) The Model 100T is equipped with a lamp voltage control circuit, which automatically corrects for the degradation of the flash lamp with age. After several years, the lamp will likely have degraded to the point that it is being driven with the maximum voltage that the power supply can deliver. If the voltage is at 1200V, it will be necessary to either replace or adjust the lamp voltage control circuit. Section 4.8.7 of the Operation Manual details the UV lamp calibration.
- (f) The sample pump diaphragm inside the analyzer should be replaced annually. Refer to the Instruction Sheet which is shipped with the replacement pump diaphragm kit.

Table 8-1: T100 Preventive Maintenance Schedule				
Item	Action	Frequency	Cal Check	Manual Section
¹ Particulate Filter	Change Particle Filter	Bi-Weekly	No	8.3.1
Perform Pneumatic Leak Check	Verify Leak Tight	Annually or after repairs involving pneumatics	Yes	8.3.6
² Pump Diaphragm	Replace	Annually	Yes	Refer to diaphragm kit instructions
³ PMT Sensor Hardware Calibration	Low-level hardware calibration	On PMT/Preamplifier changes if $0.7 < \text{SLOPE}$ or $\text{SLOPE} > 1.3$	Yes	10.7.2.8
¹ Sample Chamber Optics	Clean chamber, windows and filters	As necessary	Yes	10.7.2.2 and 10.7.2.3
¹ Critical Flow Orifice and Sintered Filters	Replace	As necessary	Yes	8.3.4
¹ These Items are required to maintain full warranty; all other items are strongly recommended. ² A pump rebuild kit is available from Teledyne API's Customer Service including all instructions and required parts (refer to Appendix B for part numbers). ³ Replace desiccant bags each time the inspection plate for the sensor assembly is removed.				

8.1.2 Analyzer Corrective Maintenance

Any analyzer problems indicated by excessive zero/span drift or breakdown and not controlled by preventive maintenance must be dealt with by immediate troubleshooting by the network operator and contact with an Enviroplan Project Manager or technical support personnel or the manufacturer if required. The field operator is encouraged to refer to Chapter 8 in the manufacturer's Operation Manual for guidance and procedures in performing corrective maintenance. All work conducted must be recorded in the site logbook, instrument maintenance log and, when required, documented on a Non-Conformance/Corrective Action form (see Section C of the QAPP).

A complete multipoint calibration of the analyzer must be performed after maintenance that requires:

- Analyzer relocation;
- Interruption of analyzer operation of more than twenty-four hours and subsequent automatic zero/span check responses exceed tolerance limits; and

- Upon component replacement which could affect calibration (e.g., UV flash lamp, PMT, other electronic components).

8.2 CALIBRATION EQUIPMENT

The primary calibration equipment used in conjunction with the TAPI T100 analyzer is a TAPI T700 gas dilution calibrator and TAPI 701H zero air supply, together with a certified (EPA protocol G-1) compressed gas cylinder of SO₂ in N₂. This system is also the equipment used for the automatic daily zero/span check of the analyzer is a Monitor Labs 8500 calibrator equipped with an SO₂ permeation tube.

This equipment should be maintained according to the manufacturer's recommendations and instrument manual. Checks as noted on the site visit checklist should be conducted and followed-up accordingly. Enter all work performed in the chronological site logbook and in the instrument maintenance log.

Network operators must work in conjunction with the Enviroplan Quality Assurance Lab personnel to ensure that all reference calibrator components are NIST-traceable and kept certified according to schedule. All traceability and original calibration documentation is archived at Enviroplan Consulting's offices in Fairfield, NJ.

8.3 MISCELLANEOUS SUPPORT EQUIPMENT

Monitoring system support equipment such as the sample delivery train components, air conditioners, heaters, etc. must be inspected and cleaned periodically for continued proper operation.

The borosilicate glass sample intake probe and manifold should be inspected weekly for visible dirt. These components should be cleaned at least once per year or more frequently if visible dirt and ambient conditions warrant. Cleaning is typically effected using distilled water and bristle brushes only. For stubborn foreign matter, a detergent may be needed, however, all residue must be thoroughly rinsed off using distilled water and the components air-dried prior to re-installation.

Sample lines should be replaced when direct is visible. Exterior dirt should not be mistaken for dirt on the interior surface of sample lines. The associated replacement interval can vary greatly, depending on ambient conditions.

Air conditioner filters should be replaced at the beginning of each cooling season. The condenser coils should also be thoroughly washed at the same time.

The exterior of the shelter structure should be closely inspected at least once each year, preferably during the warm seasons. Structural or other mechanical problems should be repaired promptly. Missing rivets or gaps in seams can be repaired using a high-quality, outdoor-use rated silicone sealant compound (e.g., Dow-Corning Silicone II). Invisible roof leaks can be repaired by painting the roof with an industrial-grade epoxy paint.

9. **TROUBLESHOOTING**

The Model T100 is designed utilizing a modular approach. The internal components of the instrument are grouped into replaceable subassemblies to facilitate fault isolation and correction. Chapter 12 ("Troubleshooting") in the Operation Manual should assist the field operator in identifying the malfunctioning component or module. The faulty module can then be replaced, thus returning the instrument to monitoring as soon as possible. The defective module can then be repaired by a technician familiar with the mechanical aspects or electrical principle involved in its operation.

The analyzer's test functions can be used to predict failures by looking at trends in their values and by comparing them values recorded for them at the factory and recorded on the *T100 Final Test and Validation Data Form* (Teledyne API P/N 04551) that was shipped with the analyzer. The analyzer site check form further provides a running record of the analyzer's parameters and test functions that should be used for predictive purposes.

A digital multimeter capable of resolving 1 mV is recommended for troubleshooting the Model T100 SO₂ analyzer.

A supply of common parts is typically a part of the network inventory. This parts stock is determined by repair history for the model analyzer in use. If the analyzer incorporates any expendable or short-life components (recommended replacement frequency of one year or less), they are normally included as part of the network inventory, thus minimizing down time of the instrument.

In all circumstances, failure or malfunction of the instrument is to be reported promptly to the field supervisor and the Project Manager. A Non-Conformance/Corrective Action plan should be developed and implemented to resolve the problem as quickly as possible, so as to minimize any associated data loss (see Section C of the QAPP).

All actions associated with servicing or repairing the instrument will be summarized in the site logbook. A similar synopsis should appear in the "comments" section of the analyzer routine check form.

FORM 5-1: SO₂ MULTIPOINT CALIBRATION FORM

Calibration Data on This Form Are For: _____ Unadjusted Cal. _____ Adjusted Cal.

Network:	Site:	Date:
Time Off-Line:	Time On-Line:	Technician:

Calibration Equipment Info.	Analyzer Mfg./Model No.: TAPI T100	S/N:	Last Cal'd:
	Calibrator Mfg./Model No.: TAPI T700	S/N:	Cal. Date:
	Gas Cylinder Supplier: Scott Marrin Gas	Cyl. Cert. Date:	Cyl. Pressure: PSIG
	Gas Cylinder ID #:	SO ₂ Cyl Conc.: ppm	Site Temp.: °C

Analyzer Calibration Settings	“As Found” (Before Any Adjustment)	“As Left” (After Adjustment)
SLOPE		
OFFSET		

INPUT GAS DATA					SO ₂ RESPONSE DATA			
Gas Ch. Display Setting	Gas Ch. Flow Rate (sccm)	Air Ch. Display setting	Air Ch. Flow Rate (sccm)	SO ₂ Gas Input Conc. (ppm)	E-out (volts)	Rec. (%F.S.)	DAS (ppm)	Δ%
OFF	OFF			0				

LINEAR REGRESSION ANALYSIS RESULTS

Slope=	Intercept=	Corr. (r)=
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NOTES:

1. A valid “As Found” P/Z/S check must be performed prior to performing an adjusted-response multipoint calibration IF the analyzer is operational and producing data.
2. If the results of the “As Found” P/Z/S check cited above exceed ±0.010 ppm for zero and/or ±15% deviation for span response, the technician should perform an “As Found” multipoint calibration prior to performing any maintenance or adjustments. The technician should then perform an “As Left” (Adjusted Response) multipoint calibration.

Comments: _____

Technician: _____

QA Review: _____

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FORM 7-1: SO₂ SYSTEM ROUTINE CHECK FORM

Network: _____ Site Name: _____

Dates of Checks:➔				
Operator's Initials:➔				

GENERAL SITE CONDITIONS

Shelter Min/Max Temp. (Must be within 20°-30° C)	Min	Max	Min	Max	Min	Max	Min	Max
Shelter and Site Conditions OK? (Y or N; Explain in "Comments" if N)								
Sample intake and lines clean, intact and free of moisture? (Y or N)								

SO₂ ANALYZER CHECKS

Analyzer Mfg./Model#: _____ S/N: _____ Last Cal. Date: _____

Analyzer in normal SAMPLE mode? (Y or N):								
Analyzer RANGE set to 500 PPB and SINGLE range? (Y or N):								
Analyzer STABIL value (PPB):								
Analyzer SAMP PRESS (in-Hg-A): (Ambient ±2 in-Hg-A)								
Analyzer SAMPLE FLOW (cm ³ /min): (650 cm ³ /min ± 10%)								
Analyzer PMT SIGNAL (mV) at SO ₂ CONC. (PPB):	PMT	SO ₂	PMT	SO ₂	PMT	SO ₂	PMT	SO ₂
Analyzer UV LAMP (mV): (1000 to 4800 mV)								
Analyzer LAMP RATIO (%): (30 to 120 %)								
Analyzer DARK PMT (mV): (-50 to 200 mV)								
Analyzer DARK LAMP (mV): (-50 to 200 mV)								
Analyzer SLOPE: (1.0 ±0.3)								
Analyzer OFFSET (mV): (<250 mV)								
Analyzer HVPS (V): (~400 to 900 V)								
Analyzer RCELL ON? (Y or N):								
Analyzer RCELL TEMP (° C): (50° C ± 1° C)								
Analyzer BOX TEMP (° C): (ambient temp + ~ 5° C)								
Analyzer PMT TEMP (° C): (7° C ± 2° C constant)								
Analyzer ETEST (mV): (2000 mV ± 1000 mV)								
Analyzer OTEST (mV): (2000 mV ± 1000 mV)								
Analyzer REF_4096_MV (mV): (4096mv±2mv and Must be Stable)								
Analyzer REF_GND (mV): (0 mv±0.5mv and Must be Stable)								
Most recent SO ₂ AutoCal (Level 2) SPAN (PPB): (400 PPB ±40 PPB)								
Most recent SO ₂ AutoCal (Level 2) ZERO (PPB): (<10 PPB)								
Any analyzer ERROR MSGS? (Y or N):								
Change sample particulate filter? (Y or N)								

Comments: _____

Technician: _____

QA Review: _____

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FORM 8-1: INSTRUMENT MAINTENANCE LOG

Mfgr:	Model:	S/N:
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Date of Maintenance	Maintenance Type & Tech Initials		Maintenance Performed (Describe)	Instrument In Use At (Network and Site)
	Preventive	Corrective		